NRL Report 7345

Biological Deterioration of Woods in Tropical Environments

Part 3 - Chemical Wood Treatments for Long-Term Marine-Borer Protection

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December 9, 1971

NAVAL RESEARCH LABORATORY
Washington, D.C.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Naval Research Laboratory Washington, D. C. 20390	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

BIOLOGICAL DETERIORATION OF WOODS IN TROPICAL ENVIRONMENTS, Part 3— Chemical Wood Treatments for Long-Term Marine-Borer Protection

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Final report on one phase of the project; work is continuing on other phases.

5. AUTHOR(S) *(First name, middle initial, last name)*

C. R. Southwell and J. D. Bultman

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 9, 1971	30	18

8a. CONTRACT OR GRANT NO. NRL Problem G04-01 b. PROJECT NO. RR 104-03-41-5503 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) NRL Report 7345 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Department of the Navy (Office of Naval Research), Arlington, Va. 22217

13. ABSTRACT

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DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Chemical preservatives						
Marine borers						
Limnoria						
Pholad						
Teredo						
Whole creosote						
Chromated copper arsenate						
Brackish-water exposure						
Seawater exposure						
Wood deterioration						
Treated tropical woods						

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PROBLEM STATUS

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AUTHORIZATION

NRL Problem G04-01
Project RR 104-03-41-5503

Manuscript submitted August 26, 1971.

BIOLOGICAL DETERIORATION OF WOODS IN TROPICAL ENVIRONMENTS

Part 3—Chemical Wood Treatments for Long-Term Marine-Borer Protection

INTRODUCTION

A complete investigation was initiated to determine the effects of long-term exposure on the resistance of natural and chemically treated woods to the attack of tropical marine and terrestrial wood-destroying organisms. In this investigation 115 wood species and six wood treatments were evaluated. Exposure studies were made in five different underwater and terrestrial sites in the very bioactive environments of the Panama Canal Zone. The first report (1) on this work covered the initial 14-month results for the 115 untreated woods, and Part 2 was the final 90-month report for the same natural woods in the underwater studies (2). This third report will be concerned with marine-borer resistance of chemically treated nonresistant woods and of combinations of chemical marine-borer inhibitors with naturally resistant woods.

One additional report on the terrestrial exposures of treated and untreated woods with a comparison of terrestrial and marine durability will complete the series.

The three significant marine borer families in the biodeterioration of wood are the Teredinidae *(Teredo, Bankia)*, Pholadidae *(Martesia)*, and Limnoriidae *(Limnoria)*. All are very active in the topical waters of the Canal Zone. The area provides an ideal location for marine exposure studies. In this narrow isthmus, secure underwater exposure facilities are available in two oceans and a brackish-water lake, each of which harbors different marine organisms (in all, 28 wood-boring species have been identified from these waters). A tabulation of all Canal Zone marine wood borers and their habitation is given in Appendix A.

Wood treatment with toxicants to achieve marine durability has been studied and used for many years. However, because of the many species of borers encountered in different waters and the wide range of tolerance of these species, the effectiveness of preservative treatments in exposure studies and in full-scale field applications has varied considerably. These unpredictable results have caused much confusion in establishing standard procedures. For example, the most widely used and generally accepted current standard is the pressure treatment of timbers with whole creosote; yet the variability in service life of such creosoted timbers from relatively short-term failures to long-term durability has long been recognized. Until recently, the reason for this variability was not clearly understood. Formerly, these differences were often attributed to inadequate creosote treatment or undesirable handling and installation practices or both. Undoubtedly, these errors have often been associated with such failures; however, with the description of a new limnoria species, *L. tripunctata* (3), an additional, previously unsuspected cause of this observed variation in service life became apparent. This species, a temperate and tropic water dweller, is implicated in the destruction of creosoted timbers by virtue of its ability to enter the treated wood soon after immersion (4-6). It has been collected from creosoted pilings and associated with the premature failure of such pilings. Whether, as indicated by Menzies and Turner (4), this creosote tolerance of *L. tripunctata* is a natural attribute for the animal, or whether it is the result of the development of a new, resistant strain, is not clear. Although its activity may vary considerably with local water conditions, where an *L. tripunctata* populations exists, there is considerable doubt whether creosoted Southern Pine or Douglas Fir timbers will serve as effective marine materials, particularly in tropic waters, where limnoria attack is intense. This creosote tolerance may also extend to other limnoria species.

Examples of limnoria damage on creosoted piles in the limnoria-active waters of the Panama Canal Zone are shown in Fig. 1 for (a) Coco Solo harbor on the Caribbean coast, with small tides and (b) Balboa harbor on the Pacific coast, with very high tides. These tidal differences are reflected in the length of the damaged areas. Cost of replacing creosoted timbers at the Pacific site alone averages 100 to 200 thousand dollars per year, and it has been estimated (7) that for all U.S. marine structures, damage caused by marine boring organisms probably costs 200 to 300 million dollars annually.

(a) Coco Solo Harbor on the Caribbean coast of the Panama Canal Zone—average tidal range is 1 foot

(b) Balboa Harbor at the Pacific entrance to the Panama Canal—average tidal range is 13 feet.

Fig. 1—Typical marine borer damage to creosoted pilings in the tropics

EXPERIMENTAL PROCEDURE

Procedures and exposure conditions for the treatment portion of this study were generally the same as for the untreated woods reported in Parts 1 and 2 (1, 2). Considerably more background material and experimental detail have been included in these first two reports.

As with the natural woods, the treated-wood marine borer studies consisted of two phases. Exposures in the first phase, which lasted for periods up to 90 months, were carried out at Naos Island in Pacific seawater and in the brackish water of Miraflores Lake; exposures in the second phase were conducted at Coco Solo in Caribbean seawater for periods up to 51 months. Views of these three test locations are presented in Fig. 2. The Pacific site was the NRL marine exposure pier adjacent to the Ft. Amador Causeway on Naos Island, about 1.5 miles seaward from the natural shoreline; there the tropical ocean water averages 81.1°F and 30.1‰ salinity, the tidal range averages 13 feet, and the water depth at the pier averages 22 feet below mean tide elevation. Brackish-water exposures were made from a spare canal lock gate moored near the center of Miraflores Lake. This body of water, which is approximately 2 square miles in area, is located between the second and third Pacific-side locks of the Panama Canal. Average elevation of the lake is 58 feet and the salinity varies with season, rainfall, and the number of lockages through the canal. Normally, the annual salinity range is between 0.2 and 0.5‰, and temperature remains fairly constant between 80° and 85°F. The third exposure site was on the Atlantic side of the Isthmus of Panama in Manzanillo Bay of the Caribbean Sea; specimens were suspended at Pier 3, at Coco Solo Naval Base, where the tidal range averages about 1 foot, water temperature averages 82.6°F, and salinity averages 31.4‰.

Samples were suspended vertically at 1.5 to 3 feet below mean low tide at the Naos Island and Coco Solo locations and 8 to 12 feet below the water surface at the Miraflores exposure site.

The first phase of the induced toxicity studies was an evaluation of six selected pressure treatments of Southern Yellow Pine and Douglas Fir. The toxic selection was made with the aid of data collected at NRL in a screening sutdy of creosote fractions and chemical preservatives (8, 9). Screening consisted of exposures of many small samples at Wrightsville Beach, N.C., for relatively short times. Also bearing on the toxic selection were suggestions obtained from well-known authorities in the field of wood preservation. Six treatments were chosen for these longer-term, larger-sample tropical water exposures.

Of the six treatments, two were the most widely used commercial preservatives for marine use: whole creosote and 70-30 creosote-coal tar solution. Two others were commercial treatments but were practically untried as marine borer inhibitors: one was a water-base chromated copper arsenate (CCA, type A) (greensalt), and the second was a mixture containing 5% tributyltin oxide (TBTO) in 50/50 creosote and coal tar naphtha. Two experimental water-base preservatives were also included, one a copper formate preservative developed at the University of Miami (10) and the other a silver nitrate treatment developed at the University of Washington.

All toxicants were induced into the wood by pressure, and the set of specimens for each treatment was prepared in the laboratories of the people specifically interested in the particular treatment, under conditions assuring optimum retention of toxicant in the wood. A summation of the preservative treatments, treating laboratories, and retention levels is presented in Table 1. Twelve replicate specimens 1.5 x 3 x 18 inches for each wood treatment, six for the seawater and six for the brackish-water sites, were exposed vertically. Twenty-one equal-size control specimens of untreated Southern Yellow Pine and Douglas Fir were similarly mounted and distributed throughout the two exposure areas. Concurrently with this study, 113 species of untreated tropical woods were identically exposed, so that comparative data for treated domestic woods and naturally resistant tropical species are now available. A complete list of the botanical and common names of all the woods studied is included in Appendix B.

Because of the higher *Limnoria tripunctata* activity on the Caribbean side of the Isthmus of Panama, and the equally intense attack from other borers, the exposure for the second

(a) Pacific Ocean site, Panama Bay, Naos Island, C. Z.

(b) Brackish-water site, Miraflores Lake, C.Z.

(c) Caribbean Sea site, Manzanillo Bay, Coco Solo, C. Z.

Fig. 2—Views of the test locations

Table 1
Preservative Treatments

Treatment	Treating Laboratories	Average Retention (lb/cu ft)
Southern Yellow Pine		
Creosote, whole, grade 1, medium residue	Koppers Co.	41
Creosote, whole, grade 1*, medium residue	NRL	40
Creosote coal tar solution—70/30	Koppers	33
Creosote coal tar naphtha 50/50 with 5% TBTO	Osmose Co.	13
Chromated copper arsenate (CCA) type A, water base (greensalt)	Koppers Co.	4.7
Copper formate (water base, thermal reacted)	National Cylinder Gas Co.	2.7
Silver nitrate (water base, thermal reacted)	University of Wash.	†
Douglas Fir		
Creosote, whole, grade 1, medium residue	Koppers Co.	5.0
Creosote, whole, grade 1*, medium residue	NRL	14
Creosote coal tar solution—70/30	Koppers Co.	4.9
Chromated copper arsenate	Koppers Co.	0.84
Copper formate (high retention)	National Cylinder Gas Co.	3.2
Copper formate (std. retention)	National Cylinder Gas Co.	2.2
Silver nitrate	University of Wash.	†

*Specimens for Caribbean exposure (1.5 x 2 x 9 inches—all other specimens were 1.5 x 3 x 18 inches).
†Autoclaved at 16 psi and 250°F, 25% aqueous solution, to refusal but retention unknown.

phase of the studies was at the Coco Solo site. In this part of the investigation selected tropical woods and Douglas Fir and Southern Yellow Pine were exposed, both pressure-treated with whole creosote and untreated. Sixteen pieces of each wood were included. Half of these were pressure-treated with whole creosote and half were exposed untreated. All Caribbean specimens were 1.5 x 2 x 9 inches and were supported vertically at a depth of 1.5 to 3 feet below mean low tide.

It was revealed in the initial phase of this study that many of the tropical woods were considerably more resistant to limnoria attack than domestic coniferous woods. Therefore, another approach in seeking borer immunity for wood is to start with one of these naturally limnoria-resistant tropical species and pressure-treat it with creosote for protection against molluscan borers.

After considerable laboratory investigation to see how well samples of these woods would accept creosote, 14 tropical species were selected for pressure-treating with whole creosote. Domestic Southern Yellow Pine and Douglas Fir were included for comparison. The tropical woods selected were not necessarily the most borer resistant. Generally, the selection was limited to woods meeting the following requirements: high resistance to one or more borer groups in the initial screening tests; density in the range of most domestic construction timbers (0.5 - 0.9); physical strength properties equal to or greater than pine or fir; adequate size and availability to warrant some potential as marine construction timber, and suitable creosote acceptance. For this last condition, a range of retention was sought so that one or two exceptionally high- and low-retention woods were included.

Eight 1.5 x 2 x 9 inch replicates of each wood species were pressure-treated with whole creosote, using the American Wood Preservers Associations full-cell procedure. These specimens were then immersed in the very borer-active Caribbean waters at Coco Solo. Methods of exposure, inspection, and removal were the same as for the treated domestic woods tested at Coco Solo.

Pacific and lake water samples of the first phase of the study were examined at 7, 14, 38, and 90 months; those of the second phase in the Caribbean at 14, 37, and 51 months.* At each period one or more specimens were removed and sectioned longitudinally for a more complete inspection.

Four numerical ratings of 0—no apparent attack, 1—slight, 2—moderate, and 3—heavy were used. Figure 3 exemplifies this rating scale. Specimens were rated separately for the three major groups of borers: teredo, pholads, and limnoria.

RESULTS AND DISCUSSION

Comparison of Pressure Treatments of Southern Pine and Douglas Fir

The two domestic woods most used with pressure preservative treatments are Southern Yellow Pine and Douglas Fir. These two were exposed at all sites, both untreated and full-cell treated with whole creosote. At the Pacific Ocean and Miraflores Lake sites all the preservatives were tried in both woods, except for the mixture containing TBTO, which was used only in pine. The results for these Southern Pine and Douglas Fir specimens afford an interesting comparison of the effectiveness of these woods as marine construction timbers. In the untreated condition no difference between the woods was detected; neither wood exhibited any natural resistance to any family of borers. Of the 113 untreated tropical woods, only two or three others had such generally low resistance to all borer groups, and considering limnoria resistance specifically, these U.S. coniferous woods were possibly the least resistant among the 115 species of untreated woods tested. It is probable that Southern Pine and Douglas Fir, with their distinct bands of very soft earlywood and hard latewood, provide the

*Caribbean exposures were terminated before 90 months because the NRL Corrosion Laboratory was moved to Key West, Florida.

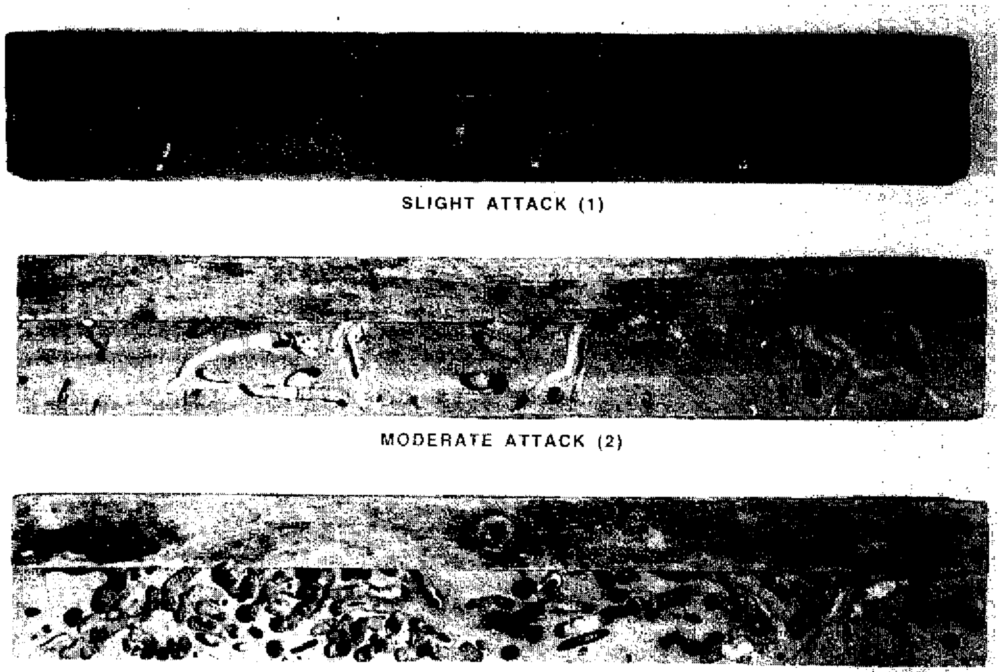

Fig. 3—Examples of slight (1), moderate (2), and heavy (3) attack ratings for teredos

most ideal type of habitat for limnoria. These small crustaceans can easily work into the soft wood and are then somewhat protected by the adjacent walls of harder wood.

The Southern Pine and Douglas Fir panels were all moderately to heavily damaged by teredos within 14 months both in the Pacific and lake exposures. At the Pacific site, where *Limnoria tripunctata* was not active, *L. lignorium* caused very little damage to any of the tropical woods throughout the exposure period, but this same borer was able to inflict appreciable attack on most of the control pieces of untreated Southern Pine within 7 months.

In the Caribbean, Southern Pine and Douglas Fir panels were all completely destroyed within 14 months by the combined attack of all borers. Repeat samples of these two woods were exposed and examined at 3 and 7 months. No detectable difference in early attack was noted for the two. On both, limnoria activity was intense, so much so that the woods had considerably smaller accumulations of marine fouling than the more limnoria-resistant tropical woods. Figure 4 shows an exterior view of a specimen of Douglas Fir after 7 months exposure at Coco Solo. The heavy limnoria activity over much of the surface and the selective attack into the soft earlywood can be seen.

With the treated samples there was considerable difference between pine and fir. Table 2 presents a summarized comparison of the two woods for three of the best preservative treatments. With Douglas Fir, the milled specimens used for the exposures did not allow an adequate amount of toxicant to be absorbed. Retentions averaged 5.0, 4.9, and 0.84 lb/cu ft for whole creosote, creosote-coal tar, and copper arsenate respectively, while the milled Southern Yellow Pine accepted 41, 33, and 4.7 lb/cu ft. These low retentions in Douglas Fir did not provide effective borer protection. With all three treatments, specimens of Douglas Fir reached heavy teredo damage levels in both Pacific ocean and brackish-lake water.

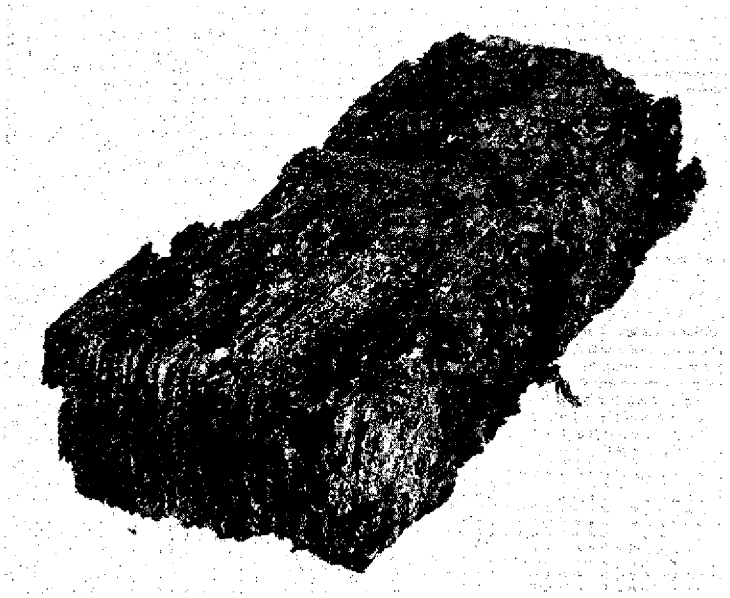

Fig. 4—Rapid limnoria attack on untreated Douglas Fir in tropical waters showing selective attack into soft earlywood—7 months' immersion in Caribbean seawater at Coco Solo, Canal Zone

Table 2
Summary Comparison of Southern Yellow Pine and Douglas Fir as Pressure-Treated Marine Timbers During The 90-Month Exposure

Preservative	General Ratings*	
	Southern Pine	Douglas Fir
Whole creosote (maximum attack any inspection)	2	3
Creosote—coal tar solution 70/30 (maximum attack any inspection)	2	3
Chromated copper arsenate (maximum attack any inspection)	1	3
Cumulative ratings (all inspections)	17	56

*Summarized from individual ratings of 0—no apparent attack, 1—slight, 2—moderate, and 3—heavy, for all borers for three time intervals and four environments.

The outer ring of sapwood that surrounds an uncut pile may make Douglas Fir sufficiently creosote-receptive for effective marine piling use, but with cut surfaces it is probably not as suitable as Southern Yellow Pine or other more creosote-receptive woods. A photograph of a creosoted Douglas Fir sample after 90 months in Pacific seawater is shown in Fig. 5. Both pholads and teredos were present in the samples. Borer populations were not dense, but the organisms that became established grew large and healthy, and once matured were able to bore into the more heavily creosoted end sections of the wood.

Fig. 5—Creosoted fir after 90 months in tropical seawater, Pacific Ocean, Naos Island, Canal Zone

To further study the creosote tolerance of mature borers, couples, consisting of pieces of creosoted wood at retentions of 5 to 37 lb/cu ft of whole creosote bolted to equal-size pieces of untreated baitwood, were exposed for 1 year in Caribbean water at the Coco Solo site. These couples have shown that, once established in the baitwood, the pholad, *Martesia*, can cross the interface into the heavily creosoted wood and apparently suffer no ill effects. A photograph of one of these couples is shown in Fig. 6. Teredos were much less active than *Martesia* in the untreated portion of the couple and during the year did not make significant penetrations into the treated wood.

Whole Creosote vs Other Creosote-Base Preservatives

The three creosote-base preservatives tried were whole creosote, creosote-coal tar, and TBTO in creosote-coal tar naphtha. In Table 3 these treatments have been compared after exposure in the tropical Pacific at Naos Island, C.Z. These comparisons are for pressure treatments in Southern Yellow Pine only. Treatment retention was highest for whole creosote at 41 lb/cu ft. Additional exposures of creosote in pine was made at Coco Solo in the Caribbean for 51 months. The results of these exposures are also included in Table 3. Creosote retentions were very high in the relatively small samples used (1.5 x 3 x 18 inches at Naos Island and 1.5 x 2 x 9 inches at Coco Solo). With these retentions, protection against ocean teredos and pholads was very good for all three treatments. However, even though Naos Island is not a site of high limnoria activity, after 90 months' exposure, all three creosote

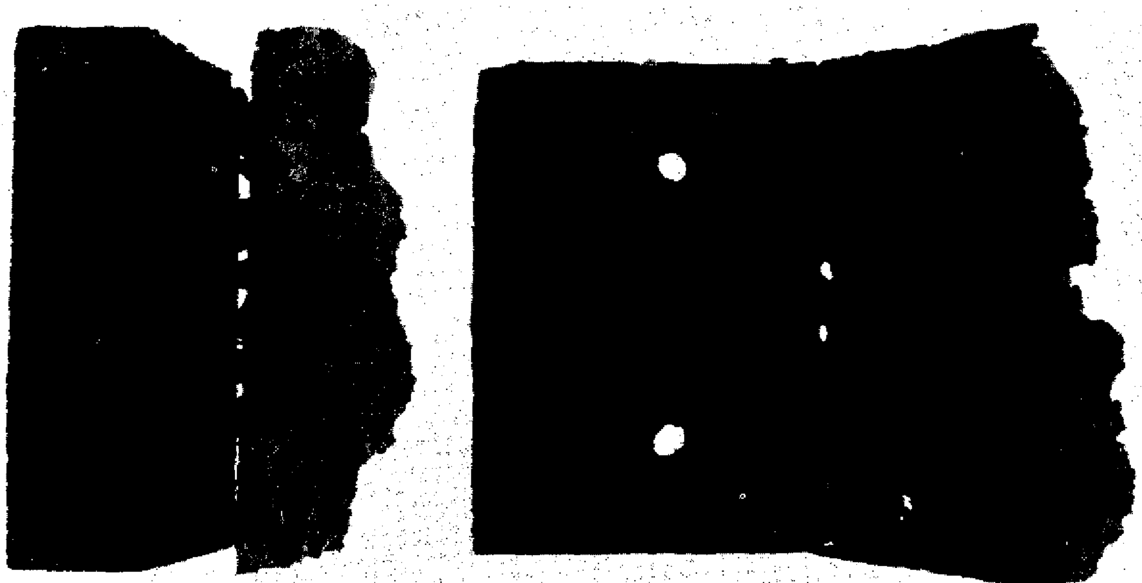

Fig. 6—*Martesia* in heavily creosoted wood couples containing untreated and pressure-treated wood after 1 year's immersion in tropical seawater at Coco Solo, Canal Zone

treatments had sustained some limnoria damage, and the TBTO-creosote-naptha samples had received a moderate attack rating (relatively high for the Naos Island water).

The lake psiloteredo, *P. healdi*, seemed much more creosote-tolerant than any of the ocean molluscan borers. While no attack occurred during the first 14 months on any of the treated woods in Miraflores Lake, by 38 months there was light attack on woods treated with the 70/30 solution, and moderate attack on those treated with whole creosote and those treated with the mixture containing TBTO. By 90 months whole creosote and 70/30 creosote-coal tar solution specimens were moderately attacked, and those with the TBTO mixture had dropped to a "heavy damage" rating.

From these data it can be seen that whole creosote is highly effective against ocean teredos and reasonably effective against pholads. The creosote-coal tar solution was almost on par, while the creosote-naphtha-base TBTO was slightly less effective. Since whole creosote in pine is the most generally used wood-preservative combination, it will be used as the criterion for the water-base preservatives to follow.

Water-Base Chromated Copper Arsenate as a Long-Term Borer Inhibitor

Since water is the cheapest, cleanest, and most available vehicle material, an effective water-base preservative for marine timbers would be a highly desirable treatment. Many water-borne materials have been tried as wood preservatives, and in some environments they have been very successful. In immersion service, however, their solubility and resulting high leaching rates usually make them unsatisfactory. A few systems employ two or more water-soluble salts and an oxidizing agent, with the resulting reactions reportedly forming insoluble toxic compounds in the wood. One of the more successful of these compounds for terrestrial

Table 3
Evaluation of Creosote-Base Preservative Treatment of Southern Yellow Pine

Preservative	Damage Ratings*								
	Teredo			Pholad			Limnoria		
	14 Mo	38 Mo	90 Mo	14 Mo	38 Mo	90 Mo	14 Mo	38 Mo	90 Mo
Pacific Exposure									
Whole creosote	0	0	0	0	0	0	0	0	1
Creosote—coal tar sol, 70/30	0	0	1	0	0	1	0	0	1
Creosote and coal tar naphtha 50/50 with 5% TBTO	0	0	2	0	0	1	0	0	2
Caribbean Exposure									
Whole creosote	0	0	0	1	0	1	0	1	1
Brackish-Lake Exposure									
Whole creosote	0	2	2	not present					
Creosote—coal tar sol, 70/30	0	1	2						
Creosote and coal tar naphtha 50/50 with 5% TBTO	0	2	3						

*Rating Scale: 0—No apparent attack, 1—slight, 2—moderate, and 3—heavy.

environments has been chromated copper arsenate (CCA), greensalt. Data obtained by Duncan and Richards (11) showed that greensalt is in fact almost nonleachable. Considering all exposures and all borer groups, the water-borne chromated copper arsenate was the best overall marine-borer preservative used in Southern Yellow Pine. Its effectiveness undoubtedly was due to the very high retentions obtained in this wood; average retention was 4.7 lb/cu ft (75 kg/m^3). However, the creosote preservative with which it is compared was also put in at maximum retentions. Only 0.84 lb/cu ft of CCA could be induced into the Douglas Fir samples, and this quantity was ineffective in the marine exposures. Teredo damage to this wood reached moderate levels within 38 months, and heavy damage resulted within the 90-month period.

In Southern Yellow Pine at the heavier retention of CCA there was no attack by teredos for the full 90-month test, either in the ocean or in Miraflores Lake. This was exceptional resistance to the brackish-water *Psiloteredo* in the lake. Of all the treated woods and the 115 species of natural woods exposed, these were the only samples that were completely resistant in the lake water.

With the exception of its superiority in the brackish-lake water, the chromated copper arsenate was approximately equal to the refusal treatments of whole creosote. A comparison of these two best preservatives is given in Table 4. The two materials were not compared in the more limnoria-active waters at Coco Solo. Under such conditions, however, there should be some additional advantage for CCA over creosote, since the copper salts have the reputation of being somewhat better limnoria inhibitors.

Table 4
Comparison of Chromated Copper Arsenate and Whole Creosote at High and Low Retentions

Preservative	Borer	Location	Damage Ratings*			Cumulative Ratings	
			14 Mo	38 Mo	90 Mo	All Exposures	Sea Only
CCA	Teredo	Seawater†	0	0	0		
Av 4.7 lb/cu ft		Brackish water‡	0	0	0		
in Southern Pine	Pholad	Seawater†	0	0	1		
	Limnoria	Seawater†	0	0	1	2	2
Creosote	Teredo	Seawater	0	0	0		
Av 41.0 lb/cu ft		Brackish water	0	2	2		
in Southern Pine	Pholad	Seawater	0	0	0		
	Limnoria	Seawater	0	0	1	5	1
CCA	Teredo	Seawater	0	2	3		
Av 0.84 lb/cu ft		Brackish water	0	2	3		
in Douglas Fir	Pholad	Seawater	0	1	2		
	Limnoria	Seawater	0	0	1	14	9
Creosote	Teredo	Seawater	0	2	3		
Av 5.0 lb/cu ft		Brackish water	2	3	3		
in Douglas Fir	Pholad	Seawater	0	1	2		
	Limnoria	Seawater	0	0	2	18	10

*Numerical ratings: 0—no apparent attack, 1—slight, 2—moderate, and 3—heavy.
†Seawater exposures: Pacific Ocean at Naos Island, Panama Canal Zone.
‡Brackish-water exposures: Miraflores Lake, Panama Canal Zone.

Results With Two Experimental Water-Base Preservatives

The development of an effective water-borne preservative holds such promise for clean, economical wood preservation that much research has been conducted in this direction; however, very little of this research has been in the marine environments. At the time this investigation was initiated (1958), experts in the field were canvassed to determine whether any then new experimental water-base treatments should be included in the long-term exposure studies. As a result, two aqueous-solution treatments were included. One was a copper formate treatment which had been developed at the University of Miami (10), and the second was a silver nitrate treatment of special interest to its developers at the University of Washington. To convert the chemicals into insoluble compounds in the wood, both of these methods require autoclaving after full-cell treatment. These two experimental preservatives were applied in the laboratories of the developers, and maximum retentions were obtained in the specimens. A summary of results with these preservatives, compared with standard whole creosote, is presented in Table 5. While the copper formate seemed superior to creosote in resisting the more creosote-tolerant brackish-water *Psiloteredo*, this was the only point of superiority for either of these two preservatives. With the ocean molluscan borers, both teredo and pholad, whole creosote was a much more effective preservative, showing only slight teredo and no *Martesia* damage at the 90-month inspection; by that time both the copper formate and silver nitrate treated specimens were heavily attacked by teredos and moderately by pholads.

Table 5
Water-Base Preservatives Compared With Whole-Creosote Full-Cell Treatment of Southern Yellow Pine

Preservative	Teredo						Pholad			Limnoria		
	Lake			Pacific			Pacific			Pacific		
	14 Mo	38 Mo	90 Mo	14 Mo	38 Mo	90 Mo	14 Mo	38 Mo	90 Mo	14 Mo	38 Mo	90 Mo
Whole creosote	0	2	2	0	0	0	0	0	0	0	0	1
Silver nitrate	0	2	2	1	2	*	1	2	*	†	†	*
Copper formate	0	1	2	2	3	*	1	2	*	1	1	*
Chromated copper arsenate	0	0	0	0	0	0	0	0	1	0	0	1

*Specimens were destroyed or missing.
†Note: Treatment-softened wood resulted in heavy surface erosion which prevented assessment of limnoria damage.

Although these two experimental preservatives may prove adequate for some northern waters, for areas of extreme borer activity they do not appear to be as satisfactory as heavy creosote or chromated copper arsenate.

Pressure-Treated Pine Compared with Woods of High Natural Resistance

The long-term data afford a comparison of woods of high natural resistance with the highly efficient preservative treatments used with domestic Southern Yellow Pine. A comparison of the exposure results obtained from the two best chemical treatments with those of the four tropical woods exhibiting the highest overall borer resistance, and with four commercial timber species marketed as marine borer-resistant woods, is presented in Table 6. Within the time span of the exposures none of the natural woods were quite as effective against the molluscan borers (teredo and pholad) as pine with either whole creosote or chromated copper arsenate. It must be recognized, however, that the treatments in pine were very heavy, probably the highest practical retention of toxicant obtainable in this wood. Even so, one species of untreated tropical wood, *Dalbergia retusa*, approached the efficiency of the treated pine in resisting molluscan borers; it was equal to the treated pine in the Caribbean exposures but sustained slightly more attack in the 90-month Pacific exposures.

Table 6
Comparison of Wood Preservatives in Domestic Southern Yellow Pine vs Borer-Resistant Natural Woods

Preservative	Damage Ratings*						
	Teredo			Pholad		Limnoria	
	Lake	Pacific	Carib.	Pacific	Carib.	Pacific	Carib.
	90 Mo	90 Mo	51 Mo	90 Mo	51 Mo	90 Mo	51 Mo
Best Two Chemical Treatments in Pine							
Chromated copper arsenate (4.7 lb/cu ft)	0	0	†	1	†	1	†
Whole creosote (40-41 lb/cu ft)	2	0	0	0	1	1	1
Four Best Natural Tropical Woods							
Dalbergia retusa	2	1	0	2	1	0	0
Dialium guianense	2	1	†	2	†	0	†
Pouteria campechiana	2	2	1	2	2	0	3
Tabebuia guayacan	3	2	1	2	2	0	1
Commercial Marine-Use Tropical Woods							
Vouacapoua americana	3	2	2	2	2	0	1
Tectona grandis	3	2	2	2	3	0	2
Ocotea rodiei	3‡	2§	2	2§	2	0§	2
Lophira procera	3‡	2	2	3	2	1	1

* Ratings: 0—no apparent attack, 1—slight, 2—moderate, 3—heavy.
† Not tested in this environment.
‡ 37-month rating—test discontinued because of heavy attack.
§ 37-month rating—samples missing at 90 months.

The commercial borer-resistant woods in general rated a little below the four best natural woods in resistance to molluscan borers and significantly below the resistance of the two best chemical treatments in Southern Pine.

In the case of limnoria damage a slightly different evaluation emerges in that many of the tropical woods show a high degree of natural resistance to these crustacean borers. In spite of the lack of activity of *L. tripunctata*, it appears of some significance that in the Pacific both of the heavy treatments in pine showed some limnoria attack while most of the better natural tropical woods did not. Untreated pine, as mentioned previously, was considerably less resistant to limnoria in the Pacific than most of the tropical wood species.

The Caribbean exposures provided somewhat more significant comparisons of limnoria resistance. There, in the presence of active *L. tripunctata*, four of the untreated tropical woods listed in the table and five other tropical species among the 44 untreated woods exposed were as good as the heavily creosoted pine in their ability to withstand limnoria damage. *D. retusa* was even better than creosoted pine, because there was no limnoria attack at all on any of the eight replicates of this wood during the 51-month immersion. The limnoria tests in the Caribbean would have given more significant information if the woods had continued on exposure to the scheduled 90 months.

Creosote Treatment of Selected Tropical Wood Species

Since creosote is a very effective toxicant against shipworms, but does not completely stop limnoria, the rate of limnoria damage is now recognized as the principal factor in the expected life of creosote-treated Southern Pine or Douglas Fir timbers. Some progress has been made in the use of double treatments of copper salts and creosote to provide additional protection against limnoria. Such double-treated piles and other preferred treatments are now being tested in Coco Solo harbor, Canal Zone, and in other locations by the Cooperative Marine Piling Committee (12). Double treatments have shown considerable promise; however, at Coco Solo after 8 years' exposure, some borer damage has been inflicted on about one half of the double-treated piles. As mentioned previously, many of the untreated tropical woods were found to possess considerably more limnoria resistance than possessed by the domestic coniferous woods. Thus, it was felt that pressure-treating such naturally limnoria-resistant tropical species with creosote might give these woods full borer protection. Fourteen selected tropical woods received such treatment.

A list of the treated tropical woods exposed is given in Table 7. Botanical and common names, air-dry specific gravities, and average creosote retentions are included. In addition, borer ratings for teredos, pholads, and limnoria are shown for each of the inspection periods of 14, 37, and 51 months.

The 14 selected tropical woods varied considerably in their acceptance of creosote, with retentions ranging from 2 lb/cu ft to 46 lb/cu ft. These retentions were somewhat related to density but apparently are considerably influenced by the type of wood grain. For example, *Licaria pittieri*, with a specific gravity of 0.50, would accept only 2 lb/cu ft of creosote, while *C. brasiliense*, with 0.69 specific gravity, retained 22 lb/cu ft.

The ensuing exposure results indicated that the creosote content of these treated tropical woods was related to resistance only in that less than 10 lb/cu ft did not seem to be sufficient to assure protection. *Cordia alliodora* with 12 lb/cu ft was completely resistant, and *Hura crepitans* with the highest retention of 46 lb/cu ft was practically as good, but the

Table 7
Selected Tropical Woods Treated With Creosote and Exposed to Intense Marine-Borer Activity in Caribbean Seawater

Wood Species	Common Names in Area of Procurement	Specific Gravity (air-dry)	Creosote Retention (av lb/cu ft)	Damage Ratings*									Cumu-lative Rating
				Teredo			Pholad			Limnoria			
				14 Mo	37 Mo	51 Mo	14 Mo	37 Mo	51 Mo	14 Mo	37 Mo	51 Mo	
Anacardium excelsum	Espavé—Panama, R.P.	0.53	20	0	0	0	0	0	0	1	1	1	3
Bombacopsis sessilis	Ceibo—Panama Canal Zone	0.45	18	0	0	0	0	0	1	0	2	1	4
Calophyllum brasiliense	María, Santa María—Panama, R.P.	0.69	22	0	0	0	0	0	0	0	0	0	0
Carapa slateri	Tangaré, Bateo—Darien, R.P.	0.55	8	0	0	1	0	0	2	0	1	1	5
Conocarpus erectus	Zaragosa—Panama Canal Zone	0.90	9	0	0	1	0	1	1	0	0	0	3
Cordia alliodora	Laurel Negro—Bocas del Toro, R.P.	0.40	16	0	0	0	0	0	1	0	0	0	1
Cordia alliodora	Laurel—Panama, R.P.	0.45	12	0	0	0	0	0	0	0	0	0	0
Couratari panemensis	Vasca—Darien, R.P.	0.52	27	0	0	0	0	0	1	0	0	0	1
Dialyanthera otoba	Miguelario—Bocas del Toro, R.P.	0.42	35	0	0	0	0	0	0	1	1	1	3
Hura crepitans	Nuno—Panama Canal Zone	0.38	46	1	0	0	0	0	0	0	0	0	1
Licaria pittieri	Jigua Negro—Darién, R.P.	0.50	2	0	2	2	1	2	2	0	1	2	12
Luehea seemannii	Guácimo—Panama Canal Zone	0.56	23	0	0	0	0	0	0	0	0	0	0
Pinus sp.	Southern Yellow Pine—U.S.A.	0.47	40	0	0	0	1	0	1	0	1	1	4
Prioria copaifera	Cativo—Panama Canal Zone	0.44	31	0	0	0	0	0	1	0	1	1	3
Pseudotsuga taxifolia	Douglas Fir—U.S.A.	0.54	14	0	0	1	1	0	1	1	1	2	7
Vochysia ferruginea	Flor de Mayo—Panama Canal Zone	0.48	32	0	0	0	0	0	0	0	0	0	0

*Damage Rating: 0—no apparent attack, 1—slight, 2—moderate, 3—heavy.

control wood, pine, with a high retention of 40 lb/cu ft showed some susceptibility to limnoria and pholads.

As with the natural woods in the Caribbean exposure, more significant data would have resulted with a longer period of exposure. Even with the shortened exposure, however, some very interesting trends are indicated. The heavily treated Southern Pine and Douglas Fir had some slight attack by all three borer types during the course of the investigation, with the Douglas Fir attaining a moderate attack rating for limnoria at 51 months. On the other hand, four of the treated tropical woods, *Calophyllum brasiliense, Cordia alliodora, Luehea seemannii,* and *Vochysia ferruginea,* were completely free of any borer damage during the 51-month exposure period, and the wood of *Hura crepitans* and *Couratari panamensis* showed only slight damage on one sample of each during the exposures.

Four of these top-rated treated woods, *H. crepitans, C. alliodora, L. seemannii,* and *C. brasiliense,* are listed as commercial foreign woods on the American market (13). *Couratari panamensis* and *V. ferruginea* are not well known but could probably be found if there were sufficient demand.

At 51 months none of the treated woods had progressed beyond a moderate attack level, and borer attack in many was just commencing. With such incomplete data, definite service life of any of the treated tropical woods cannot be predicted. The results do indicate, though, that a system of pressure-treating a naturally resistant wood with a preservative may be one of the most reasonable ways of obtaining marine construction timbers with a very long service life. The results also indicate sufficient potential to warrant discussion of the properties of a few species that appear to be most promising for further study. In such a study the test specimens would be exposed as large-size timbers, pressure-treated by commercial processes under careful supervision and exposed at a site (such as Coco Solo) where an active population of all three borer groups, especially *L. tripunctata,* exists. Test timbers should extend from the mudline to above maximum tide line.

The few species from the screening study that seem especially suitable as pressure-treated marine timbers are:

Cordia alliodora—Laurel or Laurel Negro—a medium density wood of 0.4 to 0.5 gr, with good mechanical properties and a high strength-to-weight ratio (14). It is a medium-to-large tree of frequent occurrence throughout the American tropics (15) and is reported to be one of the finest native trees for reforestation (16). While only 12 to 16 lb of creosote could be induced into this wood, this amount, combined with its high natural resistance to limnoria and teredos, made the wood practically immune to borer damage.

Calophyllum brasiliense—Maria or Santa Maria—a tall, straight-trunked forest tree of fairly frequent occurrence in Panama, where the wood is commercially available. It is a hard, strong, but easily worked, medium-to-heavy wood (0.7 sp gr). Maria wood, while much more resistant than domestic conifers, is not as naturally resistant to borers as some of the other woods tested (2), but it has the unusual combination of high strength and density with open pores that permit a thorough impregnation of creosote. It was possible to induce 22 lb/cu ft of creosote into the Maria samples. With this treatment there was no attack by any borers during the 51 months of exposure in Caribbean seawater.

Couratari panamensis—Vasca—a medium-density wood with good mechanical properties, which comes from a large forest tree, but one that is little known to commerce. Another species of this genus, *C. pluchra,* has been reported resistant to marine borers (13). In the untreated exposures in this study, Vasca showed good to moderate resistance to most borers. It accepted creosote very well with average full-cell retention of 27 lb/cu ft. With this treatment there was only a slight bit of pholad activity at the 51-month period.

Luehea seemannii—Guácimo—a medium-density (0.56 sp gr), moderately hard, fine-textured, easily worked wood that takes a smooth finish. It is a medium-to-large-sized tree of common occurrence in the lowland forests of Central America. The wood took treatment well, accepting 23 lb/cu ft of creosote, and with this retention there was no borer attack at all during the 51 months in Caribbean water.

Hura crepitans—Nuno—a very large tree of common occurrence in the American tropics. In some places it forms nearly pure stands. The wood is light and soft, specific gravity 0.38. Its resistance to teredo was very low, and untreated samples were destroyed before limnoria resistance could be evaluated. When full-cell treated with creosote, it accepted 46 lb/cu ft, and at that retention proved almost completely resistance to all borers throughout the 51-month Caribbean exposure.

Vochysia ferruginea—Mayo—a tall, straight-trunked forest tree of frequent occurrence in the Central American tropics. The wood is of light to medium density (0.48 sp gr), with a high strength-to-weight ratio. Its natural resistance to teredo is very low, and untreated samples were destroyed by teredine borers before long-term limnoria resistance could be established. However, the wood accepted creosote well, and when full-cell treated it retained 32 lb/cu ft. During the 51-month exposure in the Caribbean, the creosoted samples showed no attack from any borers.

Besides these Central American woods, it would be desirable to investigate the best woods from other areas where an adequate supply of exportable timber exists; woods that have some degree of natural resistance and that accept creosote well. Such a wood is Apitong, from the Philippines, which Stearns (17) describes as a tall, straight tree providing strong heavy timbers with remarkable stiffness and abrasion resistance, but with the extremely rare characteristic for dense woods of having open, unclogged pores. The advantage of such a structure is the ease and the thoroughness with which the wood can be creosoted.

Southern Yellow Pine and Douglas Fir are among the lowest-resistance woods to all borers, especially to limnoria. Practically all U.S. efforts in borer-control research have been toward making these woods resistant with improved preservative treatments. In this study, and in many other marine exposures, whole creosote has proven to be an effective deterrant for molluscan borers but not for the crustaceans (limnoria). Since only a small percentage of the treated timbers used are for very limnoria-active marine environments, it would be economically feasible to select more limnoria-resistant wood species and treat them with whole creosote for these exposures. With such combinations there could be a number of advantages, namely (a) a possibility of effective borer resistance over very long periods of exposure, (b) higher strength and abrasion resistance with some woods which would eliminate the need for frequent replacement due to breakage and wear, a considerable advantage, since many soft-pine piles and timbers fail from these causes before borer infestation, and (c) reduction in preservative costs by the elimination of double treatments and, since most woods can be treated with a lesser amount of creosote than that required for pine, by the reduction in the quantity of creosote used.

The results of this study seem to provide sufficient evidence of the potential of these combinations to warrant additional study toward obtaining the optimum wood-creosote combination and comparing this with the best single- and double-treated timbers and piles of Southern Yellow Pine.

SUMMARY OF RESULTS

1. The long-term exposures in the very borer-active waters of the Panama Canal Zone have enabled a thorough evaluation of the induced and naturally occurring marine borer inhibiting chemicals. From the three exposure sites, two oceans and a brackish-water lake, 28 species of marine wood borers have been identified.

2. Damage by the three major groups of marine borers (teredo, pholad, and limnoria) was rated separately. Of the three, teredos were the most easily controlled by preservatives, followed by pholads and limnoria respectively.

3. Southern Yellow Pine and Douglas Fir were the two major woods in which the chemical preservatives were tried. A comparison of these woods showed that in the untreated condition both were highly susceptible to all three groups of borers and, relative to other untreated species, were especially low in resistance to limnoria. Southern Pine accepted heavy treatments of preservatives under pressure and showed excellent durability when so treated. The milled Douglas Fir specimens were difficult to treat with preservatives, and this wood seems less suitable for squared marine timbers.

4. High retentions of type A chromated copper arsenate (CCA) and medium-residue grade 1 whole creosote were the two most effective preservatives in Southern Pine for seawater exposure; the two were about equally efficient in this environment. The CCA, however, was clearly superior to creosote and the other preservatives in resisting the brackish-water *Psiloteredo.*

5. The creosote coal-tar solution and a mixture of creosote and coal tar naphtha with 5% tributylten oxide (TBTO) were also excellent preservatives for Southern Yellow Pine, but they were slightly less effective than the whole creosote. The observed differences may have been a result of the lower retentions of total preservative rather than actual differences in the preservatives.

6. Water-borne type A chromated copper arsenate gave the best overall protection of any of the preservatives tried and provided appreciably higher durability than the other two experimental water-base materials included in the studies.

7. Southern Yellow Pine with the optimum high-retention preservative treatments was generally superior to the most resistant natural tropical woods in respect to the molluscan borers (teredo and pholad). With limnoria, some of the untreated tropical woods showed slightly higher resistance than the heavily creosoted Southern Pine.

8. A few of the well-known commercial marine construction timbers such as Greenheart and Teak, were considerably less durable than the high-retention preservative treatments in Southern Yellow Pine.

9. The follow-up exposure studies in the Caribbean in which selected tropical wood species of relatively high limnoria resistance were combined with a good molluscan borer

deterrent indicated that some of these creosote-treated tropical woods may offer the most promising method of obtaining very durable marine construction timbers for heavily borer-populated waters.

ACKNOWLEDGMENTS

This study could not have been accomplished without the cooperation of a large number of people. Especially noteworthy was the guidance and assistance of Drs. J. M. Leonard and A. L. Alexander of NRL. Dr. T. R. Sweeney, formerly of NRL, and Mr. T. R. Price, of the Chemistry Division at NRL, did much of the preliminary work leading to the selection of preservatives to be tested and arranged for treatment of the pine and fir test specimens. Mr. B. W. Forgeson of NRL, formerly Scientist-in-charge of the Canal Zone Corrosion Laboratory, was very active in the early phases of the study and contributed a great deal to the overall success of the work. Mr. C. W. Hummer, Jr., formerly of NRL, did much of the experimental work on treating of tropical wood species and, with Mr. A. P. Turner of the Canal Zone Corrosion Laboratory, supervised much of the field work and offered many helpful suggestions.

The cooperation of the William F. Clapp Laboratories is gratefully acknowledged, particularly that of their past president, the late Mr. A. P. Richards, who made two trips to Panama to assist in the inspection of marine borer samples. Mrs. Dorothy J. Wallour of the Clapp Laboratories provided invaluable assistance in the identification of borer species.

A special thanks is due Dr. Ruth D. Turner, Museum of Comparative Zoology, Harvard University, for correcting and updating the table of borer binomials presented in Appendix A to conform to current usage.

Botanical identification of the woods required the participation of expert botanists and wood anatomists. The Yale School of Forestry and the Smithsonian Institution supplied the people with the necessary knowledge and ability, principally Dr. W. L. Stern from the Smithsonian and Dr. K. L. Chambers and the late Dr. G. K. Brizicky from Yale; Mrs. Mary F. Southwell of the Index Nominum Genericorum Project at the Smithsonian reviewed all botanical and common names of the woods studied to assure correct listing in the appendix.

Finally, many organizations and individuals assisted in the tropical wood collection phase of the study, especially the Panama Canal Company and the former head of the Canal Zone experimental gardens, Mr. Walter Lindsay. The United Fruit Company and numerous lumber dealers and boat builders of Panama supplied valuable assistance and materials.

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APPENDIX A

Marine Borers in Canal Zone Waters*

Miraflores Lake (Brackish Water)	Pacific Ocean (Naos Island)	Caribbean Sea (Coco Solo)
Psiloteredo healdi (Bartsch) 1931	*Lyrodus pedicellatus* (Quatrefages) 1849	*Teredo bartschi* Clapp 1923
Nausitora dryas (Dall) 1909	*Uperotus panamensis* (Bartsch) 1922	*Teredo furcifera* von Martens 1894
Bankia gouldi (Bartsch) 1908	*Teredo clappi* Bartsch 1923	*Teredo clappi* Bartsch 1923
	Nausitora dryas (Dall) 1909	*Teredothyra dominincensis* (Bartsch) 1921
	Bankia bipalmulata (Lamarck) 1801	*Teredo johnsoni* Clapp 1924
	Bankia carinata (Gray) 1827	*Nototeredo knoxi* (Bartsch) 1917
	Bankia cieba Clench & Turner 1946	*Lyrodus massa* (Lamy) 1923
	Bankia destructa Clench & Turner 1946	*Teredo navalis* Linné 1758
	Bankia fimbriatula Moll & Roch 1931	*Lyrodus pedicellatus* (Quatrefages) 1849
	Bankia gouldi (Bartsch) 1908	*Teredo portoricensis* Clapp 1924
	Bankia campanellata Moll & Roch 1931	*Teredo somersi* Clapp 1924
	Bankia zeteki Bartsch 1921	*Nausitora sp.*

APPENDIX A (CONTINUED)

Miraflores Lake (Brackish Water)	Pacific Ocean (Naos Island)	Caribbean Sea (Coco Solo)
	Limnoria lignorum (Rathke) 1799	*Bankia carinata* (Gray) 1827
	Martesia striata (Linné) 1758	*Bankia cieba* Clench & Turner 1946
		Bankia fimbriatula Moll & Roch 1931
		Bankia fosteri Clench & Turner 1946
		Bankia gouldi (Bartsch) 1908
		Bankia campanellata Moll & Roch 1931
		Limnoria lignorum (Rathke) 1799
		Limnoria tripunctata Menzies 1951
		Martesia striata (Linné) 1758

*D. B. Wallour, 13th Progress Report of Marine Borer Activity in Test Boards Operated During 1959, William F. Clapp Laboratories, Report 11466, 1960. Corrected and updated to conform to current usage by Dr. Ruth D. Turner, Museum of Comparative Zoology, Harvard University.

APPENDIX B

Botanical and Common Names of Woods Studied

Acabú—see *Zanthoxylum belizense*
Acapú—see *Vouácapoua americana*
Aguacatillo—see *Phoebe johnstonii*
Ajo—see *Caryocar sp.*
Alazano—see *Calycophyllum candidissimum*
Albarco—see *Cariniana pyriformis*
Alcarreto—see *Aspidosperma megalocarpon*
Alcornoque—see *Mora oleifera*
Alfaje—see *Trichilia tuberculata*
Algarrobo—see *Hymenaea courbaril*
Almácigo—see *Bursera simaruba*
Almendro—see *Coumarouna oleifera*
Almond—see *Terminalia catappa*
Amargo-amargo—see *Vatairea sp.*
Amarillo—see *Terminalia amazonia*
Amarillo de Guayaquil—see *Centrolobium orinocense*
Amarillo Negro—see *Lafoensia punicifolia*
Anacardium excelsum—Espavé
Andira inermis—Cocú
Angélique—see *Dicorynia paraensis*
Anime—see *Tetragastris panamensis*
Aspidosperma megalocarpon (probably)—Carreto, Alcarreto
Astronium graveolens—Zorro, Zorillo, or Ron-ron
Australian Cypress Pine—see *Callitris glauca*
Avicennia marina—Mangle Salado
Azobe—see *Lophira procera*
Bala—see *Lophira procera*
Bálsamo—see *Myroxylon balsamum*
Bambito—see *Nectandra whitei*
Basra Locus—see *Dicorynia paraensis*
Berba—see *Brosimum sp.*
Bogamani—see *Virola koschnyi*
Bombacopsis quinata—Cedro Espino
Bombacopsis sessilis—Ceibo
Bongassi—see *Lophira procera*
Bronze Shower—see *Cassia moschata*
Brosimum sp.—Berba, Guayabo Blanco
Bursera simaruba—Almácigo, Indio Desnudo
Byrosonima crassifolia—Nance
Cabimo—see *Copaifera aromatica*
Caimito—see *Chrysophyllum cainito*
Callitris Glauca—Australian Cypress Pine
Calophyllum brasiliense—María
Calycophyllum candidissimum—Alazano, Lemonwood, Lancewood
Caoba—see *Swietenia macrophylla*
Caraño—see *Trattinickia aspera*
Carapa slateri—Cedro Macho, Tangaré
Carapa sp.—Cedro Vino
Carbonero de Amunición—see *Colubrina glandulosa*
Cariniana pyriformis—Chibugá, Albarco
Carreto—see *Aspidosperma megalocarpon*
Caryocar costaricense—Henené
Caryocar sp.—Ajo
Cassia moschata—Bronze Shower
Cativo—see *Prioria copaifera*
Cedrela mexicana—Cedro Amargo
Cedrela sp.—Cedro Granadino
Cedro Amargo—see *Cedrela mexicana*
Cedro Espino—see *Bombacopsis quinata*
Cedro Granadino—see *Cedrela sp.*
Cedro Macho—see *Carapa slateri*
Cedro Vino—see *Carapa sp.*
Ceibo—see *Bombacopsis sessilis*
Centrolobium orinocense—Amarillo de Guayaquil
Cerillo—see *Symphonia globulifera*
Chibugá—see *Cariniana pyriformis*
Chlorophora tinctoria—Mora
Chrysophyllum cainito—Caimito, Star Apple
Chuchupate—see *Guarea longipetiola*
Coco—see *Lecythis ampla*
Coco—see *Lecythis or Manilkara*
Cocobolo—see *Dalbergia retusa*
Cocú—see *Andira inermis*
Colubrina glandulosa—Carbonero de Amunición

Conocarpus erectus—Zaragosa
Copaifera aromatica—Cabimo
Cordia alliodora—Laurel Negro
Cornus disciflora—Mata Hombro
Corotú—see *Enterolobium cyclocarpum*
Coumarouna oleifera—Almendro
Couratari Panamensis—Vasca
Crillo—see *Minquartia guianensis*
Croton panamensis—Sangre
Cuajado—see *Vitex floridula*
Cutarro—see *Swartzia panamensis*
Dalbergia retusa—Cocobolo
Dalienze—see *Terminalia myriocarpa*
Dialium guianense—Tamarindo
Dialyanthera otoba—Miguelario
Dicorynia paraensis—Angélique, Basra Locus
Diphysa robinioides—Macano
Douglas Fir—see *Pseudotsuga taxifolia (menziasi)*
Ekki—see *Lophira procera*
Ensiva—see *Ocotea dendrodaphne*
Enterolobium cyclocarpum—Corotú
Erythrina glauca—Gallito
Eschweilera (probably)—Guayabo Macho
Espavé—see *Anacardium excelsum*
Gallito—see *Erythrina glauca*
Gavilán—see *Pentaclethra macroloba*
Genipa americana—Jagua
Gliricidia sepium—Bala, Mata Ratón
Gorogán—see *Virola koschnyi*
Greenheart—see *Ocotea rodiei*
Guácimo—see *Luehea seemannii*
Guaragao—see *Guarea guara*
Guajacum officinale—Lignum Vitae
Guarea longipetiola—Chuchupate
Guarea guara—Guaragao
Guayabo Blanco—see *Brosimum sp.*
Guayabo Macho—see *Eschweilera*
Guayacán—see *Tabebuia guayacan*
Guayacán Negro—see *Tabebuia chrysantha*
Henené—see *Caryocar costaricense*
Hippomane mancinella—Manzanillo
Hura crepitans—Nuno
Hyeronima alchorneoides—Pantano
Hymenaea courbaril—Algarrobo
Iguanillo—see *Lonchocarpus sp.*
Indio Desnudo—see *Bursera simaruba*
Insibe—see *Ocotea dendrodaphne*
Iron Wood—see *Lophira procera*
Jagua—see *Genipa americana*
Jigua Negra—see *Licaria pittieri*
Lafoensia punicifolia—Amarillo Negro
Lagunçularia racemosa—Mangle Blanco
Lancewood—see *Calycophyllum candidissium*
Laurel Negro—see *Cordia alliodora*
Lecythis ampla—Coco
Lecythis sp.—Coco
Lemonwood—see *Calycophyllum candidissimum*
Licania arborea—Raspa
Licaria pittieri—Jigua Negra
Lignum Vitae—see *Guajacum officinale*
Lonchocarpus sp.—Iguanillo
Lophira procera—Bongassi, Ekki, Azobe
Luehea seemannii—Guácimo
Macano—see *Diphysa robinioides*
Macano Blanco—Unknown genus
Macho—see *Tetrathylacium johansenii*
Magnolia sororum—Vaco
Mahogany—see *Swietenia macrophylla*
Malvecino—see *Sweetia panamensis*
Mamecillo—see *Pouteria campechiana*
Mancha—see *Virola sebifera*
Mangle Blanco—see *Laguncularia racemosa*
Mangle Rojo (Atlantic)—see *Rhizophora mangle*
Mangle Rojo (Pacific)—see *Rhizophora brevistyla*
Mangle Salado—see *Avicennia marina*
Mangilido—see *Ternstroemia seemannii*
Manilkara sp.—Coco
Manilkara bidentata—Níspero Balata
Manilkara chicle—Níspero Zapote
Manilkara sp.—Rasca
Manwood—see *Minquartia guianensis*
Manzanillo—see *Hippomane mancinella*
María—see *Calophyllum brasiliense*
Mata Hombro—see *Cornus disciflora*
Mata Ratón—see *Gliricidia sepium*
Mayo—see *Vochysia ferruginea*
Miguelario—see *Dialyanthera otoba*
Minquartia guianensis—Crillo, Manwood
Mora—see *Chlorophora tinctoria*
Mora oleifera—Alcornoque
Myroxylon balsamum—Bálsamo
Nance—see *Byrsonima crassifolia*
Naranjillo—Unknown genus
Naranjito—see *Swartzia simplex*

Native Oak—see *Quercus sp.*
Nazareño—see *Peltogyne purpurea*
Nectandra whitei—Bambito
Nicaraguan Pine—see *Pinus caribaea*
Níspero Balata—see *Manilkara bidentata*
Níspero de Monte—see *Pouteria chiricana*
Níspero Zapote—see *Manilkara chicle*
Nuno—see *Hura crepitans*
Ocotea dendrodaphne—Ensiva or Insibe
Ocotea rodiei—Greenheart
Palo de Sal—see *Pelliciera rhizophorae*
Panamá—see *Sterculia apetala*
Pantano—see *Hyeronima alchorneoides*
Paramachaerium gruberi—Sangrillo Negro
Pelliciera rhizophorae—Palo de Sal
Peltogyne purpurea—Nazareño
Pentaclethra macroloba—Gavilán
Phoebe johnstonni—Aguacatillo
Pinus caribaea—Nicaraguan Pine
Pinus sp.—Southern Yellow Pine
Pithecellobium mangense—Uña de Gato
Pithecellobium saman—Rain Tree
Platymiscium pinnatum—Quirá
Pouteria campechiana—Mamecillo
Pouteria chiricana—Níspero de Monte
Prioria copaifera—Cativo
Psuedotsuga taxifolia—Douglas Fir *(menziasi)*
Quercus sp.—Roble de Monte, Native Oak
Quirá—see *Platymiscium pinnatum*
Rain Tree—see *Pithecellobium saman*
Rasca—see *Manilkara sp.*
Raspa—see *Licania arborea*
Rhizophora brevistyla—Mangle Rojo (Pacific)
Rhizophora mangle—Mangle Rojo (Atlantic)
Roble de Monte—see *Quercus sp.*
Roble de Sabana—see *Tabebuia pentaphylla*
Ron-ron—see *Astronium graveolens*
Sambogum—see *Symphonia globulifera*
Sangre—see *Croton panamensis*
Sangrillo Negro—see *Paramachaerium gruberi*
Sigua—Unknown genus
Southern Yellow Pine—see *Pinus sp.*
Star Apple—see *Chrysophyllum cainito*
Sterculia apetala—Panamá
Swartzia panamensis—Cutarro
Swartzia simplex—Naranjito
Sweetia panamensis—Malvecino
Swietenia macrophylla—Mahogany, Caoba
Symphonia globulifera—Sambogum, Cerillo
Tabebuia chrysantha—Guayacán Negro
Tabebuia guayacan—Guayacán
Tabebuia pentaphylla—Roble de Sabana
Tamarindo—see *Dialium guianense*
Tangaré—see *Carapa slateri*
Teak (Burma)—see *Tectona grandis*
Teak (Canal Zone grown)—see *Tectona grandis*
Tectona grandis—Teak (Burma)
Tectona grandis—Teak (Canal Zone grown)
Terminalia amazonia—Amarillo
Terminalia catappa—Almond
Terminalia myriocarpa—Dalienze (Panamanian grown)
Ternstroemia seemannii—Manglillo
Tetragastris panamensis—Anime
Tetrathylacium johansenii—Macho
Trattinickia aspera—Caraño
Trichilia tuberculata—Alfaje
Uña de Gato—see *Pithecellobium mangense*
Vaco—see *Magnolia sororum*
Vasca—*Couratari panamensis*
Vatairea sp. (probably)—Amargo-amargo
Virola koschnyi—Bogamani, Gorogán
Virola sebifera—Mancha
Vitex floridula—Cuajado
Vochysia ferruginea—Mayo
Vouacapoua americana—Acapú
Zanthoxylum belizense—Acabú
Zaragosa—see *Conocarpus erectus*
Zorillo—see *Astronium graveolens*
Zorro—see *Astronium graveolens*
UNIDENTIFIED—Macano Blanco
UNIDENTIFIED—Naranjillo
UNIDENTIFIED—Sigua